In-Car SMPSU

for the OSCAR MP3-CD-player

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The OSCAR Stand-Alone MP3 Player described in last year's September issue appears to be very popular with our readers. So popular in fact, that a large number would also like to use it in their car, boat or caravan. Using the DC/DC-converter described here will make that easier, from the power supply perspective at least.

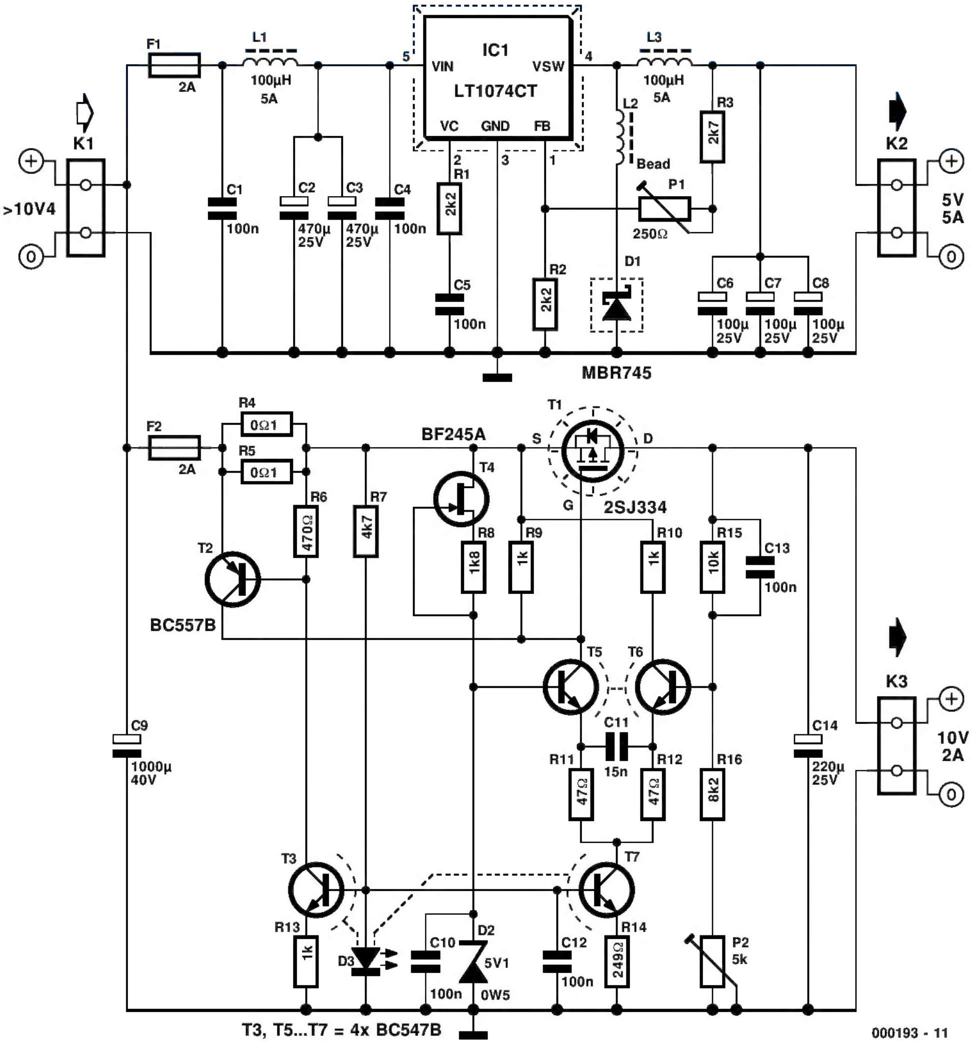
We really have ourselves to blame for this. In the first instalment of the series of articles describing the OSCAR, we carelessly let it slip that it would be advisable to use a special DC/DC converter to power this MP3-CD-player for mobile use. As a result, one can promptly expect the question 'when are you publishing such a converter?' Consequently, we immediately got to work and developed one. The end result is described below. It turns out that the required electronics is actually quite reasonable.

Two voltages

The OSCAR requires two (stabilised) power supply voltages: +5V/2A and +12V/2A. The exact current consumption will depend on the actual CD-ROM drive and hard disk used.

To derive these voltages from a 12 V battery appears to be a 'piece of cake', in the first instance. Anyone with even a little experience in electronics will immediately suggest a 'big' three-legged regulator for the 5 V supply. It would also appear reasonable to simply obtain the 12 V supply by direct connection to the battery.

However, it isn't quite so easy. An 'ordinary' 5 V voltage regulator would have to dissipate a lot of power and, concerning the 12 V supply, we have to remember that the battery voltage in a car varies signif-



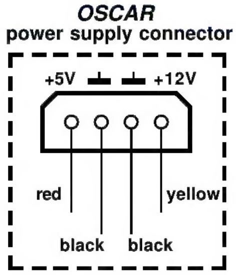


Figure 1. The schematic of the automotive power supply. P1 and P2 allow accurate adjustment of the output voltages.

icantly during use. Depending on the circumstances, the voltage can swing between about 11 V and 14.4 V. In some cases this maximum may be even higher!

The problems concerning the 5 V supply are solved by avoiding a linear regulator and using a switching step-down (buck) converter instead. Even when the battery voltage is as high as 14.4 V the dissipation will be manageable.

For the 12 V power supply a low-dropout voltage regulator will suffice. This voltage is used only for the running mechanisms and may be a lot smaller in practice. The OSCAR continued to function without any problems when the power supply was lowered to 8 V. We settled on a regulated voltage of 10 V. This is easily obtained from the battery voltage with relatively simple means. The dissipation is low enough so that there is no need to resort to a switching regulator.

5 V/5 A

To generate the 5 V power supply we applied the LT1074CT, which has featured in Elektor Electronics on earlier occasions. This is an integrated switching regulator that can deliver a generous 5 A and requires very few external components. While configured as a classic 'chopper', a number of refinements to this IC make it possible for it to be used as a positive-to-negative converter, negative 'boost-converter' and negative flyback-converter. Since the LT1074CT is provided with an analogue multiplier in the negative feedback loop, it reacts to input voltage variations almost without delay, while at the same time, the loop gain is independent of the input voltage. Furthermore, the LT1074 possesses a robust current limiting circuit, which makes the IC nearly insensitive to overloads and short circuits. The input voltage range during normal use stretches from 8 V to 60 V.

A glance at the schematic depicted in **Figure 1** reveals at the top the 5 V regulator, built around the LT1074CT (IC1). As can be seen, there are indeed very few external components. We will now examine the schematic a little closer.

The input voltage is decoupled with L1 and C2, C3 and C4 for the purpose of filtering the switching pulses. F1 prevents a short circuit on the battery in the event of a fault.

R3/P1/R2 define the output voltage. P1 permits the output voltage to be adjusted to exactly 5 V. The voltage divider is intentionally connected behind L3 in order to automatically compensate for the voltage drop across the noise suppression choke.

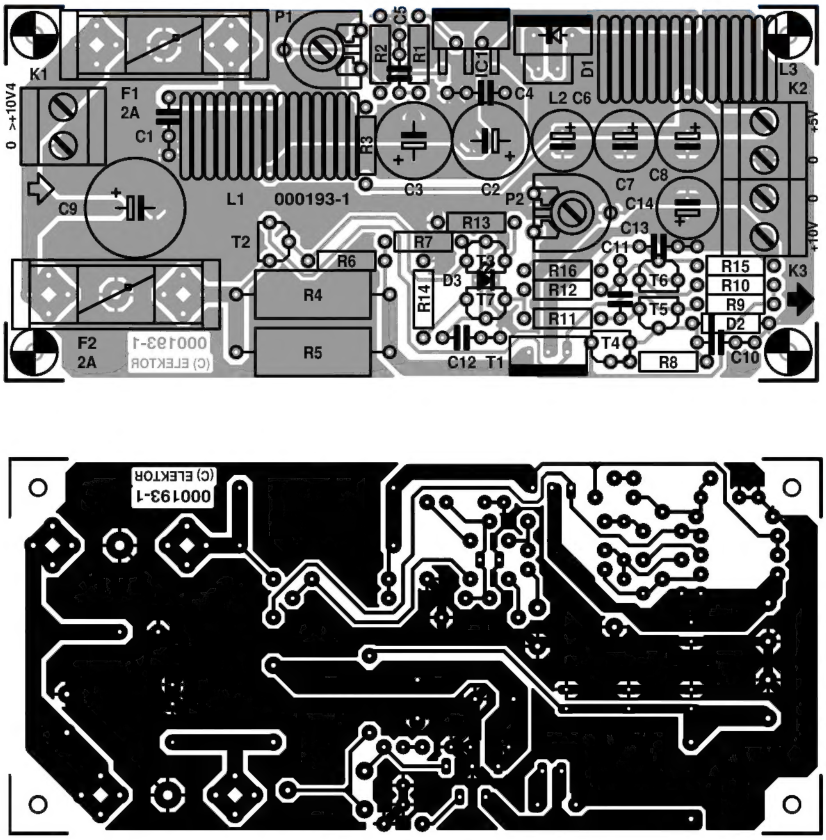


Figure 2. The printed circuit board is compact en easy to construct. Components IC1, D1 and T1 have to be cooled.

COMPONENTS LIST

Resistors:
R1,R2 = 2kΩ2
R3 = 2kΩ7
R4,R5 = 0Ω1 5W
R6 = 470Ω
R7 = 4kΩ7
R8 = 1kΩ8
R9,R10,R13 = 1kΩ
R11,R12 = 47Ω
R14 = 249Ω
R15 = 10kΩ
R16 = 8kΩ2
P1 = 250Ω preset H
P2 = 5kΩ preset H

Capacitors:
C1,C4,C5,C10,C12,C13 = 100nF ceramic
C2,C3 = 470µF 25V radial
C6,C7,C8 = 100µF 25V radial
C9 = 1000µF 40V radial
C11 = 15nF
C14 = 220µF 25V radial

Inductors:
L1,L3 = 100µH 5A, e.g., SFT12-50 (TDK)
L2 = ferrite bead (see text)

Semiconductors:
D1 = MBR745
D2 = zener diode 5.1V, 0.5W
D3 = LED, flat, red
T1 = 2SJ334 (Toshiba)
T2 = BC557B
T3,T5,T6,T7 = BC547B
T4 = BF245A
IC1 = LT1074CT (Linear Technology)

Miscellaneous:
K1,K2,K3 = 2-way PCB terminal block, lead pitch 5mm
F1,F2 = fuse, 2A, with holder and cap for PCB mounting
PCB, order code 000193-1 (see Readers Services page)

The network R1/C5 is required to frequency compensate the IC. Ferrite bead L2 may optionally be inserted to reduce possible RF emission caused by the switching of D1. This bead is not strictly necessary and may be replaced with a wire link.

L1 and L3 are two standard 100 µH/5 A noise suppression chokes. These are easily obtained and have the advantage that they may be used with both the LT1074CT and the 2 A regulator LT1076CT. The latter is pin compatible and may be used instead if the current under consideration does not exceed 2 A.

The parallel connection of electrolytic capacitors C2/C3 and C6/C7/C8 may look a little strange initially, but has the advantage that the size of the current pulses per capacitor are reduced (longer life!) and that the total ESR and parasitic inductance are significantly smaller (smaller spikes).

Both the 10 V and the 5 V power supplies are protected with 2 A fuses against sustained overloads. If it is really necessary to obtain a current of 5 A from the 5 V power supply then the fuse needs to be increased (to 2.5 A at 12 V in), but because the load from the OSCAR is much smaller, a 2 A fuse is perfectly adequate.

10 V / 2 A

For the 10V/2A regulator a discrete solution was selected, so that it could easily be tailored to the application. Conceptually it is a low-drop regulator around a difference amplifier with current limiting to make the regulator short-circuit proof.

The voltage reference is a simple JFET current source (T1) and a 5.1 V zener diode (D2). The base of T5 forms the non-inverting input of a difference amplifier. The output voltage is fed back via voltage divider R15/R16/P2/C13 to the inverting input. P2 sets the desired output voltage, and this may be a little more or a little less than 10 V.

Considering the application, the internal gain (mainly defined by R9/R11/R12) and as a consequence the ripple rejection has been kept modest. In this configuration the output voltage at 2 A drops about 0.4 V, which is completely acceptable in this case.

The final stage consists of a single P-channel power MOSFET type 2SJ 334. Because the drain functions as the output, the drop-out voltage is defined by the channel resistance of the MOSFET, the shunt for the current limiting (R4/R5) and the fuse. The minimum resistance of the transistor plus the shunt is less than 110 mΩ.

The MOSFET is a logic-level type that starts to conduct at 2 V and is practically fully on at 4 V. The usual application for the 2SJ 334 is actually as a switch, but this transistor also functions very well in the linear range. V_{DSS} may be up to 60 V and the drain current may be as high as 30 A DC. The SOA (safe operating area) of the 2SJ334 permits a maximum current of nearly 3 A during a short circuit with an input voltage of 14.4 V; this is the design value of the current limiting circuit.

At increasing temperatures, T2 will limit earlier and earlier, which is a desirable additional safety feature, considering the typical environment in which the power supply is intended to operate (a hot car in the summer sun).

Current limiting takes place because the collector of T2 lowers the V_{GS} of T1. The drive current for the gate is a maximum of 4 mA through R9 (defined by current source T7). By biasing the base of T2 (voltage across R6) the voltage required to turn T2 on can be significantly reduced. This has the desirable consequence that the drop-out voltage of the entire regulator is reduced because the resistance of the shunt R4/R5 can be made smaller.

The bias of T2 is provided by current source T3, which uses the same reference LED (D3) as current source T7 for the difference amplifier. The current for the LED is via R7 directly obtained from the input voltage. On the PCB, T3 and T7 are placed on opposite sides of D3 so that they will track each other's temperature and minimise the thermal drift of the power supply. Thermal stability was also considered while designing FET-based current-source T4: the selected current of 0.6 mA is the value at which the temperature coefficient of a BF245A is minimised.

C11 and C13 are added to improve the pulse response of the voltage regulator. C10/C12 and C14 are additional decoupling. R10 is included in the collector leg of T6 in order to make good control of the adjustment of the difference amplifier possible.

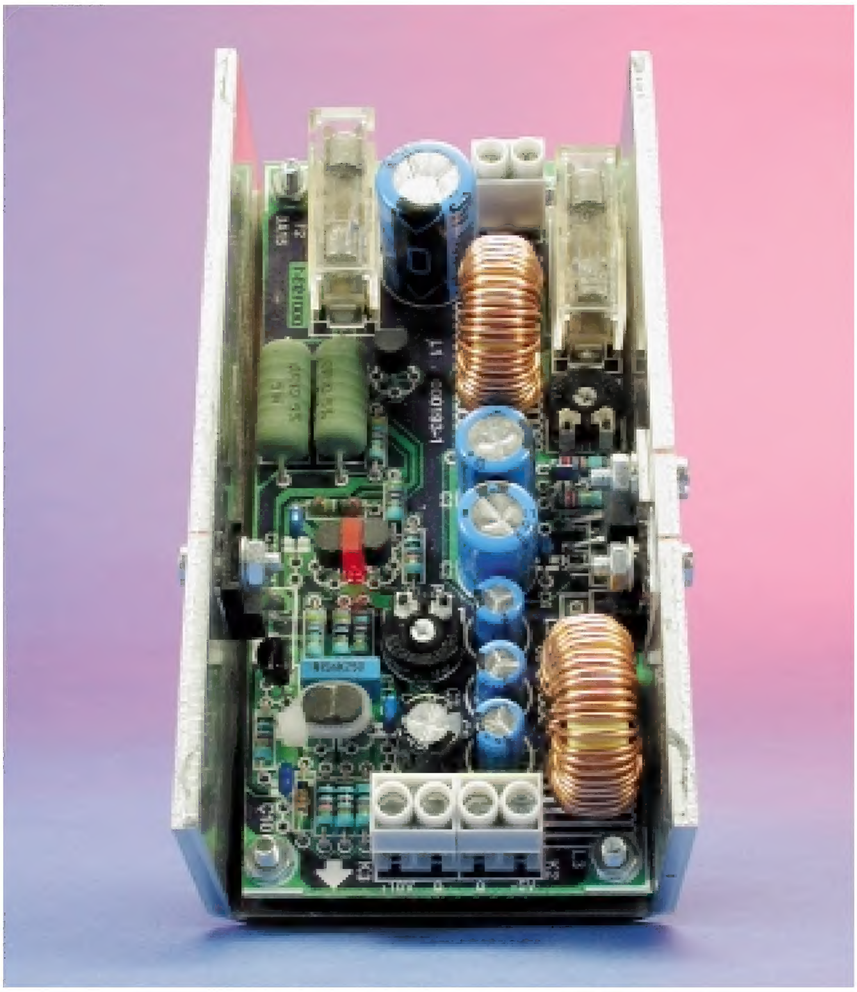


Figure 3. The do-it-yourself aluminium channel affords both cooling and protection.

Printed Circuit Board

A circuit board has (naturally) been designed for the In-Car Power Supply onto which the entire circuit including fuses and suppression chokes are fitted in a compact manner. **Figure 2** shows the layout of this PCB. There are almost no peculiarities regarding the assembly of the PCB. We've already mentioned the thermal coupling of T3/D3/T7. The same is true for the difference amplifier T5/T6. Good thermal coupling will improve the stability and it is therefore advisable to clamp both transistors together with, for example, a cable tie.

As can be seen, the input and outputs are along the short edges on opposite sides of the PCB. The connections for the OSCAR are in the same order as those of a PC power supply connector: +5V/0/0/+10V. For clarity, this connector is also shown in the schematic of **Figure 1**.

It is important that IC1, D1 and T1 are provided with sufficient cooling. For the prototype we used a 'box' with a do-it-yourself heatsink made from a 3 mm thick sheet of aluminium. This sheet was bent into a U-channel with the same inner dimensions as the length and width of the PCB and a height (approximately 35 mm) such that the sides protrude just above the components when the PCB is fitted inside (on plastic stand-offs). This not only ensures excellent cooling but also creates a very robust power supply module that can withstand a little abuse expected in automotive applications. **Figure 3** shows the appearance of the finished circuit board and heatsink. On the other hand, of you have no desire to bend your own U-channel, a nearly identical result can also be obtained by using two pieces of L-shaped extrusion.

The case of the LT1074CT (IC1) is used to connect the aluminium sheet to ground, by not isolating it. The case of the 2SJ334 is made from plastic and does not need additional isolation. Diode D1 also needs to be cooled and has to be electrically isolated because the cathode is internally connected to the case. This can be done using a mica washer. Use thermal paste when mounting IC1, D1 and T2 to the heatsink (apply thinly!).

A standard Y-adapter for PC power supplies can be used for the connection between the power supply, the CDROM drive and the main circuit board of the OSCAR: one male/large to two female/large. The connector at the male end can be disassembled. The pins can be pulled from the housing by pushing on the locking tabs.

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